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Phytogeographical notes on the Rocky Mountain region
I. Alpine region

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The alpine region, roughly speaking, is the region between the perpetual snow and the timber line.

THE UPPER LIMIT, THE PERPETUAL SNOW LINE

A perpetual snow line cannot be spoken of in the southern Rockies. Even the highest peaks do not have a perpetual snow cap like Mt. Shasta or Mt. Hood. This is probably due to the less amount of moisture and precipitation. It is true that many of the peaks have perpetual snow on them, but this snow is mostly in the form of snow-drifts and small glaciers, especially on the northern or northeastern side. The amount of snow depends to a great extent on local conditions, as for instance on an exposure to the northwestern winds or partial protection from the direct action of the summer sun. The Snowy Range of Colorado has more snow than the much higher Gray's Peak, Sierra Blanca, or Mount Massive. In the Canadian Rockies and especially in the Selkirk Mountains the conditions are different and more like those of the European Alps. There the highest peaks have a perpetual snowcap and the glaciers extend far down in the valleys. In northern Montana, as for instance in the Sperry Glacier region, are found the only places in the United States where in the Rockies there are glaciers of any great extent, notwithstanding the fact that the Montana mountains are considerably lower than those of Colorado.

THE LOWER LIMIT, THE TIMBER LINE

The timber line is by no means a well-defined boundary line. It is in reality a broad zone in which the woody vegetation gradually thins out from the dense forest to the last krumholz. In nature there is not found any sharp line between two regions, but only a gradual transition zone between them.

Different authors have fixed the timber line differently, as for instance:

1. At the forest line; i. e., where the continuous forest stops.

2. At the grove line; i. e., where the trees cease to form communities of larger or smaller size.

3. At the tree line; i. e., where the arboreal species cease to form trees.

4. The absolute timber line; i. e., where these species disappear altogether, even as krumholz.

To me it seems superfluous to consider more than two of these "lines," viz. the "forest line" and the "absolute timber line," which may be called the Lower and the Upper Timber Lines. But to fix the limit between the alpine region and the subalpine region at either of the two would be erroneous in certain respects. The region between these two timber lines is a transition zone between the two, or it may be still better called a zone of strife. A continuous warfare goes on between the forest and the alpine grassland. A seed from the forest succeeds in germinating between the low alpine plants. A tree grows up. The alpine plants are smothered in the shade. More tree seeds have a chance to germinate and a grove is formed and the forest region is carried upwards.

On the other hand, snow and wind kill the trees on the edge of the forest or the grove, the shade is gone and the alpine plants soon take possession. But more on this subject below.

The width of this transition zone or zone of strife depends on many factors. In one place the forest meets a steep cliff and stops abruptly. In such places there is no transition zone. In other places the lower timber line has been pushed down by a ledge of snow thick enough to last the larger part of the summer and having the power of smothering the trees, but not the herbaceous alpine vegetation. Still above the lower timber line at these places, there might be found isolated trees or groves of trees a thousand feet higher up, especially on higher ground, where the snow has not been so deep. In other places the lower timber line might have been pushed down by wind, not so much by its mechanical force as by its desiccating effects.

In treating the alpine region, I would be inclined to place the boundary at the lower timber line, i. e., the forest line, so as to include all open spaces of the transition zone as these have a flora alpine in character. In treating the subalpine region, however, I would place the boundary at the absolute timber line, so as to include the groves, isolated trees, and krumholz as well. The groves, if of any size, contain not only the trees themselves, but also wood plants and underbrush belonging to the subalpine region. They are either encroaching on the region above or are themselves remnants of a former forest. So are also the isolated trees and krumholz, although not associated with other plants of the forest.

In a mountain region extending through twenty degrees of latitude, from lat. 35° to lat. 55° (the Rockies north of 55° have not been considered in my work), the altitude of the timber line necessarily varies greatly. In Colorado the lower timber line is found at an altitude of between 3,200 and 3,400 m. and the upper at 3,400 to 3,500 or rarely 3,600 m. In Montana the lower one is at 2,200–2,500 m. and the upper 2,500–2,700 m. In the Canadian Rockies they are even lower.

FACTORS GOVERNING THE TIMBER LINE

The conditions that have been given as causing or modifying the timber line are:

1. A decreased temperature during the growing season.
2. Too short a growing season.
3. Late frost on account of lack of protection from snow.
4. Strong desiccating winds.
5. Deep snow.
6. Form of precipitation.
7. Large mountain masses.
8. Exposure to and protection from direct sunlight.
9. Physiographical barriers.
10. Ecological barriers.
11. Economic timber line.

LOW TEMPERATURE

It is natural that too low a temperature should be one of the important factors causing the disappearance of the forest. The temperature during the winter has, however, very little influence upon the growing of trees. It is shown that the temperature in temperate regions in the winter often is much lower than in many places in the arctic. It is doubtful if the temperature in the alpine region of Colorado ever becomes as low as on the plains of Montana, where some years ago it was recorded as 65° F. below zero. The only place within the alpine region of the Rockies where a record has been kept during the winter is on the top of Pikes Peak, and here only for a few years. No such low temperature has been recorded there. It is during the growing season that a low temperature limit for forest growths can be spoken of, for during the winter, when the life functions of the plants lie dormant, a few degrees more or less makes in reality no difference. Köppen claims that no trees can grow at a place where the mean temperature during the warmest months of the year does not reach 10° C. Schroeter gives a table taken from the records of the meteorological central station at Zürich in which are given the mean temperatures in July at fifteen stations at the timber line in Switzerland. The mean temperature ranges from 7.75° C. at Zermatt to 15.4° at Monte Generoso. This shows that the timber line may reach a little higher than the isotherm 10° C. and in other cases not reach it. Schroeter is particular enough to mention that at Monte Generoso the low timber line is not an artificial one made by man. See below. The arctic timber line seems to be more coincident with the isotherm 10° C. for July than the timber line in the mountains.

SHORT GROWING SEASON

Another cause of the timber line is the shortness of the growing season. This, it may be, is just as important a factor as the preceding. When speaking of the arctic timber line, it is easy to see that this factor acts parallel to the preceding, for near the sea-level places of the same isotherm in the summer have about the same length of summer, but not so in the mountain regions. In the heads of valleys, where big snowdrifts are formed during the winter and melt late in the summer, and along glaciers and permanent snow the frost is kept longer in the ground and the growing season is naturally shortened. Therefore, in many places in the Rockies, the timber line is a thousand feet or more lower in the valley heads than on the slopes on the sides. The shortness of the season may have also another effect on the timber line, i. e., the seeds would not have time to ripen. This may be of great importance in accounting for the arctic timber line, but it can have very little influence on the alpine timber line, for most of the conifers that reach the timber line have winged seeds, which are easily carried above the line of maturing seed and then can germinate there.

LATE FROST

Another factor which has been given as having effect on the timber line is late frost in the spring, killing the new sprouts. As the conifers, which are most affected, do not readily produce a second crop of shoots the same season, the forests after a few repeated frosts will soon be killed. In such a way large districts of pine forest were destroyed in Montana a few years ago.

STRONG DESICCATING WINDS

One of the most important factors is strong wind. This factor has been much underestimated in earlier times, but later writers on the phytogeography of the arctic regions have recognized it more and more. In my belief it is one of the most important factors in the Rockies. The trees at the timber line and especially those few isolated stragglers above the real forest line show marked effects from the wind. The trees are not only low, stunted, gnarled, ragged, with enormously elongated lower branches often spreading on the ground, but conspicuously one-sided, telling at the glance the direction of the prevailing winds. But the mechanical influence of the wind is not the most important, however. Of greatest importance are its desiccating effects, especially in the winter. This effect of the wind has been recognized even in arctic regions, but it must be taken into consideration still more in the mountains. The timber line is much lower on the north side of the Alps than on the south side. This is due not only to the difference in temperature (for the difference in altitude should not be so great), but still more to the desiccating northern winds. In some places in Montana these winds are northerly, but in southeastern Colorado and southern Utah they are from the southwest, and it is on this side of the mountains that the timber line is the lowest. In the Abajo Mountains of southeastern Utah, for instance, there is no timber line at all on the southern and western sides, for no timber is growing between the semi-arid cedar-pinyon belt and the top of the mountains. The whole southern and western slopes of the mountains proper are covered by a semi-arid grass formation. The highest peaks (altitude about 11,000 feet) just reach the timber line on the eastern and northern sides, only one or two hundred feet belonging to the alpine region. The desiccating effects of the winds are increased by the thinness of the atmosphere.

DEEP SNOW

Deep snow is also a factor. As the desiccating wind lowers the altitude on the wind-swept ridges so does the snow in the heads of the valleys. I have already mentioned that the great snow-drifts or glaciers here shorten the growing season. But the snow-drifts have also a direct mechanical influence on the timber line in the way of smothering the tree vegetation. Herbs and low shrubs can withstand being covered by snow much better than a tree, for their growing season does not begin before the snow is practically off the ground, while the tops of the trees may be above the snow and exposed to the summer heat months before the snow cover of their roots and lower branches has melted. The lower portion of the tree is cut off from the air while the upper portion is already in vital activity. It is easy to distinguish trees stunted by the action of the wind from those stunted by the smothering snow. In the former the lower branches are enormously developed compared with the upper, and often creeping along the ground, while in the latter the lower branches are dead and covered by fungi or their mycelia.

The usual condition in the Rockies is, that wherever there is a large valley head, where the snow has a chance to lodge, this is always devoid of trees, except in places of higher ground, where the snow-drift has not been so deep and has had time to melt earlier in the summer. On such higher places there are often groves or isolated trees. The absence of trees in such a valley head is due less to the shortness of the season, produced by the snow than to the smothering of the tree vegetation.

FORM OF PRECIPITATION

Another important factor influencing the timber line is the form of precipitation. In high altitudes the air is too rare to hold much moisture and the rain falls at the least lowering of the temperature. The rain falls therefore either in the form of mists or in light showers, which only wet the surface of the ground. It may be sufficient to keep alive the low rosettes or cushions of the alpine vegetation, but it is not sufficient for the deep-rooted trees. Furthermore, if a little heavier rain should come, the water would rush down the steep slopes of the mountains, not having time to sink down into the ground. The tops of the mountains are therefore arid, because the air is too rare to hold much moisture and quickly gives it up in light showers. Nowhere in the Rockies proper is the moisture very great. In the foot-hill regions and on the surrounding plains the temperature is too high in the summer to allow any precipitation. These zones are therefore also arid. It is at middle elevations that the precipitation is the greatest. The air here is dense enough to hold more moisture and the temperature low enough to allow precipitation. It is also at middle altitudes that we find the forest areas in the Rocky Mountain region.

LARGE MOUNTAIN MASSES

In the Swiss Alps, observations have been made that in regions of large mountain masses, as for instance in the Monte Rosa region and the Engadine and others, the timber line is higher than on isolated mountains. I have not seen any satisfactory explanation of this fact. It may be due partly to the fact that the central mountains of such massed groups are more or less protected from the desiccating winds. It may be due also to the circumstances that in the winter more snow lodges between the mountains, the melting of it is more retarded, and the water is more arrested in its downward course by the trees and their roots. The air in the summer time would be therefore, from the evaporation, more loaded with moisture, which would naturally also benefit the mountain tops. Whatever the real cause may be, it seems as if the observations made in Switzerland hold good in the Rockies. From my own experience, I know that the timber line in the isolated Belt Mountains and Crazy Mountains in Montana is much lower than in the main Rockies, as for instance in the Yellowstone Park. The Belt Mountains would not be high enough to have a timber line if they were in the Rockies. So also in the Wahsatch and La Sal Mountains, the timber line is much lower than in the Rockies of Colorado. Even in the Colorado Rockies themselves, the timber line seems to be higher in places where the mountains are more massed. So for instance is it higher on Mount Massive and other mountains around Leadville than on the more isolated Pikes Peak, Sierra Blanca, or Longs Peak. I understand that on the isolated Mount Shasta, the timber line is much lower down than on the peaks of the Sierra Nevada, but here it may depend upon the proximity of the ocean, the greater moisture, and the consequently larger snowcap on Mount Shasta.

EXPOSURE TO SUNLIGHT

Exposure to the direct sunlight and protection from it evidently also have influence on the altitude of the timber line, though perhaps not so much as one might expect. The insolation on the mountain tops in direct sunlight is very great. Schroeter estimates that on the top of Mont Blanc it is 26 per cent stronger than in Paris. The Rockies of Colorado have about the same height as Mont Blanc and are situated from 5° to 8° farther south, and the insolation is fully as great. The amount of light and heat which can be absorbed by the plant is therefore much greater on the mountain tops than on the plains. The radiation is also very great in the higher altitudes so that the temperature in the shadow is much lower. According to Schroeter the timber line lies 100–200 meters higher on the southern side than on the northern, and DeCandolle claims that the limiting line of vegetation, of plants in general, is at an average of 200–300 meters higher on the equatorial side. These statements cannot be verified in the Rockies. The timber line in Colorado is, perhaps, higher on the northern side, but this is probably due to other conditions. The timber line trees of Colorado are mainly *Picea Engelmannii*, *Abies subalpina*, and *Pinus aristata*. The first two are trees that need a great deal of moisture, and their seedlings require shade. These two trees are therefore more confined to the more shady and wetter northern slopes, where they also extend higher up. *Pinus aristata* is a tree that stands much more drought and is found more on the southern slopes, but it is a tree of little value as a forest tree, growing scatteringly only. To me it appears to be a species which has passed its best development and is in process of dying out.

PHYSIOGRAPHICAL BARRIERS

One of the conditions modifying the altitude of the timber line is to be found in physiographical barriers. Among these may be counted snowdrifts and glaciers, but these have been already mentioned. Besides these, the most important are precipitous cliffs and rock-slides. Very little needs to be said about these barriers. Neither gives the forest trees a chance to grow. Meeting one of these barriers, the timber may cease to grow thousands of feet below the physiological timber line. Wherever a steep cliff arrests the forest, many of the alpine plants will be found growing in the crevices, hundreds or even a thousand feet lower than usual, and there are a few plants characteristic of the rock-slides. These may be best included in the alpine vegetation.

ECOLOGICAL TIMBER LINE

Sometimes an ecological timber line is mentioned, i. e., where bacteria in the soil and other organisms necessary for the growth of trees cease to exist. Theoretically, I can easily see that such a timber line may exist, but practically I have no information that such a one is found in the Rocky Mountains, distinct from the merely physiological one. No investigation in this line has been made.

ECONOMIC TIMBER LINE

In Switzerland there exists also an economic timber line. The alpine meadows are there used as summer pastures for sheep and goats. These animals make depredations on the young trees and hinder the spreading of the forest, but in many places the subalpine forest is actually cut down by men to make room for more pastures. In either case the alpine conditions will be brought further down the mountains and the timber line lowered. Such an economic timber line cannot be said to exist in the Rockies.

ALPINE VEGETATION

After having discussed the causes of the timber line, it is easier to define what an alpine plant is. In short, it is a plant that can endure the climate of the mountains above the timber line. It is a plant that requires less heat during the growing season than the forest trees, or that can survive a shorter growing season, or is less affected by frost, and besides can better withstand desiccating winds, deep snow, reduced precipitation, etc., or a combination of such conditions. Some authors claim that alpine and arctic plants are xerophytes, but they are not necessarily so. While most of the plants of alpine and arctic regions can withstand a great deal of drought, in fact are xerophytic plants, it is not the case with all. Not a few of the arctic-alpine plants require a great deal of moisture, growing only below and around snowbanks, or in springy or boggy ground, as for instance several species of *Ranunculus*, *Saxifraga* (in extended sense), *Salix*, and many grasses and sedges. There are in the arctic-alpine regions even true aquatics, as for instance among the phanerogams, *Catabrosa aquatica*, *Phippsia algida*, *Sparganium minimum*, and *S. hyperboreum*, and a few species of *Potamogeton*.

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